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Application

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Title:

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Method And System For Distributed Navigation

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METHOD AND SYSTEM FOR DISTRIBUTED NAVIGATION

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application relates to issued U.S. patent application Ser. No. 6,266,615
entitled "Method And System For An Interactive And Real-Time Distributed Navigation
System" by HaiPing Jin, issued on July 24, 2001, and to co-pending U.S. patent
application Ser. No. 10/408325, entitled "Method and System For Prediction-Based
Distributed Navigation", by Chao et al., filed on April 8, 2003, herein incorporated in
10 their entirety by reference.

BACKGROUND INFORMATION

Field of Invention

15 The present invention relates generally to navigation systems and location-based
information delivery, and more particularly, to a method and system for a distributed
navigation system wherein a client and a server communicate to carry out distributed
navigation tasks.

Description of Related Art

20 Presently, a rapid growth in technological fields such as the personal digital
assistant (PDA) and cellular telephones has fueled consumer interest in products that
provide on-call real-time guidance and communication. One such technological advance
is a navigation system that allows its users to reach destinations by providing turn-by-turn
25 instructions along a calculated route.

Conventional navigation systems are typically satellite-based Global Positioning System (GPS) devices which have been incorporated into automobile navigation systems, for additional information regarding conventional navigation systems, refer to U.S. Pat. Nos. 5,938,720, 5,928,307, 5,922,042, 5,912,635, 5,910,177, 5,904,728, 5,902,350, all
5 incorporated herein by reference. Such conventional automobile navigation systems, however, are expensive and inconvenient to use. Therefore, there is a need to incorporate navigation capabilities so that a user may access real-time turn-by-turn route instructions via personal handheld devices such as a wireless cellular phone or a personal digital assistant (PDA) device.

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Several technical obstacles prevent efficient use of navigation systems incorporated into personal handheld devices. One such obstacle is the amount of geographic data needed to provide reasonably detailed navigational information. Small handheld devices comprise limited embedded memory that may not be adequate for
15 storing a large amount of geographic information essential for navigational purposes. This obstacle can be overcome in a distributed navigation system comprising a server-client structure, wherein the navigation functions are partitioned and assigned among one or more distributed servers and the handheld device or client.

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Due to limited client memory capacity, conventional distributed navigation systems assign a majority of nominal route calculation tasks to the server, and allocate rerouting calculations almost exclusively to the server. In order to retrieve and display navigation information to the user, the client must frequently communicate with the

server. Such constant communication may be time consuming and the information may be inaccurate due to communication delays. Furthermore, the capacities and capabilities of handheld devices or clients are diverse and evolve over time, some devices comprise adequate memory capacity to carry out partial or complete reroute tasks independently of the server.

SUMMARY OF THE INVENTION

The present invention provides a method and system for a distributed navigation system. The system comprises a client integrated with a mobile communication device (e.g. PDA, cellular telephone, etc.) and a server communicating via wireless carriers and the Internet.

In one embodiment, the server obtains a user's initial position via the client and proceeds to calculate a nominal route to a user-designated destination. The server then sends navigation information to the client and the client displays turn-by-turn navigation instructions to the user. Moreover, while the user is traveling from the initial position to the destination, the client periodically queries the user's position with positioning techniques such as the Global Positioning System (GPS). If a deviation from the nominal route is detected, the server and/or the client recalculate a new route from the user's current position to the destination. Rerouting task assignment between the server and the client may vary according to the memory and/or processing capabilities of the client and a predetermined "corridor" area surrounding the nominal route may be used to determine the reroute task division.

In a second embodiment, in addition to dynamic reroute task division between the server and the client, communication between the client and the server may be initiated by event triggers such as periodic weather updates, advertisements from local vendors, and traffic updates. The client processes information retrieved from the server during such event triggered communication and may present the user with a reroute option.

The present invention reduces excessive reroute communication between the client and the server in a distributed navigation system by storing additional corridor mapping information in the client. The reduced communication between the client and the server further diminishes possible reroute errors caused by communication delays. Moreover, the amount of additional corridor information stored in the client is dynamic and may depend on factors such as the client's storage and/or processing capabilities.

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BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings that are incorporated in and form a part of this specification illustrate embodiments of the invention and together with the description, serve to explain the principles of the invention:

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FIG. 1 is an architectural diagram illustrating an embodiment of an interactive real-time distributed navigation system.

FIG. 2 is an architectural diagram illustrating an alternative embodiment of an
10 interactive real-time distributed navigation system.

FIG. 3 is an illustrative flow chart showing the steps for communication between client and server in a real-time distributed navigation system according to one
15 embodiment of the present invention.

FIG. 4 is an illustrative flow chart showing the steps for communication between client and server in a real-time distributed navigation system according to an alternate
embodiment of the present invention.

20 FIG. 5 is a navigation routing diagram illustrating a server-calculated route from a user origin to a destination and a corridor area surrounding the route in which a client is capable of rerouting independently of the server, according to one embodiment of the present invention.

DETAILED DESCRIPTION

The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. In the following description, specific nomenclature is set forth to provide a
5 thorough understanding of the present invention. It will be apparent to one skilled in the art that the specific details may not be necessary to practice the present invention. Furthermore, various modifications to the embodiments will be readily apparent to those skilled in the art and the generic principles herein may be applied to other embodiments not necessarily enumerated herein. Thus, the present invention is not intended to be
10 limited to the embodiments shown but is to be accorded the widest scope consistent with the principles and features described herein.

A key component of a navigation system is the determination of the location (or position) of a user. It is intended that the term location referred to herein comprises a
15 geographic location or geographic information relating to the position of an object. A location may contain three-dimensional information that completely defines the exact position of an object. In some additional embodiments, a location may contain information that is not sufficient to completely define the position of an object. Broadly defined, as used herein, a location also may include speed, time, direction of movement,
20 etc. of an object.

One skilled in the art would appreciate that the format with which a location is expressed is not critical to some embodiments of the invention. For example, in some

embodiments, location information is presented in the format of (x, y), where x and y are two ordinates that define the geographic location, i.e., a position of a user. In an alternative embodiment, location information is presented by longitude and latitude related information. In another embodiment of the present invention, the location
5 information also includes a velocity element comprising a speed component and a heading component.

FIG. 1 shows an architecture for an interactive real-time distributed navigation system in accordance to one embodiment of the present invention. The various
10 components and their interaction will now be described. Wireless device **101** may take the form of a cellular telephone, satellite telephone, wireless Personal Digital Assistant (PDA), personal computer or other suitable device having wireless communications capability. Wireless device **101** is equipped with positioning capability that takes the form of, for example, Global Positioning Systems (GPS), Enhanced 911 (E911), or some
15 other positioning systems as they become available. One skilled in the art will appreciate that the present invention is not limited to any particular positioning technology. In one embodiment, wireless device **101** is manufactured with built-in positioning capabilities.

Wireless device **101** need not carry map information, or may carry some map
20 information, depending on the designed storage capability of the wireless device **101**. Such a system is described as a distributed system and will be further discussed below.

In one embodiment, the capabilities of wireless device **101** are enhanced through interfacing with modular attachments. A major function of wireless device **101** is to provide an interface between the invention and a user. Furthermore, as will be described more fully below, wireless device **101** provides a user interface for displaying graphical, textual or audible information. The user interface incorporates the user's sensory capabilities within the invention, allowing the user to interact with electromechanical components of the invention, such as by allowing the user to relay and receive location information by means of audible signals, voice, or audiovisual, graphical, or combination thereof of location information displayed or transmitted on wireless device **101**. Where a text-displaying device is used, enhanced performance is achieved through wireless device **101** displaying several lines of text.

In another embodiment comprising an enhanced video display, wireless device **101** displays maps and enhanced directional information. In another embodiment, wireless device **101** is directionally oriented through gyroscopic or geomagnetical enhancements allowing wireless device **101** or server to provide real time location and orientation information. One skilled in the art realizes that many more implementations are possible for wireless device **101** without deviating from the teachings of this invention.

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As further shown in FIG. 1 wireless carrier **103** provides wireless connectivity between wireless device **101** and navigation server **109** to be described further below. Examples of wireless carrier **103** include cellular telephone carriers and satellite

communications carriers. In achieving wireless connectivity, wireless carriers provide an existing infrastructure for the wireless devices and distributed navigation servers.

Because of the adaptive interaction with the user, information ranging from general to very specific is relayed to the user for a wide range of navigation applications.

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While keeping within the teachings of the invention, wireless carrier **103** provides positioning information such as through GPS, E911 or other positioning systems.

Alternatively, positioning information is obtained through a third party means and is then used by wireless carrier **103**. For example, wireless service resellers, wireless internet
10 service providers (ISPs), or satellite wireless carriers, among others, provide the services necessary to practice the invention. In an embodiment of the invention, wireless carrier **103** receives and transmits analog or digital information from the wireless device **101** and directs such information downstream to other components of the invention. Similarly, wireless carrier **103** receives information from components of the invention and then
15 directs such information to wireless device **101**.

As shown in FIG. 1, wireless carrier **103** is connected to gateway **105** which provides an interface to network **107**. Gateway **105** is provided by, among others, wireless carriers, ISPs, or other telecommunications providers. In one embodiment of the
20 invention, network **107** is the Internet. The Internet provides advantages because it is a widely distributed network reaching many areas of the world. In another embodiment, network **107** is implemented as a proprietary network. By implementing a specialized

network, network **107** may be customized to provide minimal latency and optimal performance.

As shown in FIG. 1, a navigation server **109** is incorporated as part of the invention by communicating via network **107**. Navigation server **109** may comprise street map information, traffic, weather, and other navigation-related as well as points of interest information to facilitate accurate navigation and flexibility. In this manner, wireless device **101** is not burdened with carrying all the necessary information required to process proper navigation. In one embodiment, navigation server **109** also processes location specific information such as real-time traffic information. In an alternative embodiment, traffic information may be obtained from a group of other service providers. By observing and comparing their positions, speeds and times, and making further comparisons with nominal street speed limits in a map database, real-time traffic information is generated and then used by the invention. At each juncture towards a destination, the system dynamically determines the optimal route for a particular user responsive to ever changing conditions. For example, where due to changed conditions a first route becomes less optimal, a second route is generated and presented to a user. An optimal route is determined in several ways depending on a user's preference. For example, an optimal route can be based on minimum time, minimum distance or minimum consumption of fuel.

An alternative embodiment of the system architecture of the present invention is shown in FIG. 2. As shown in FIG. 2, wireless device **201**, wireless carrier **203** and

navigation server **207** are substantially similar to their counterparts described in FIG. 1. Direct links **205**, however, provide an alternative embodiment to the function of gateway **105** and network **107** of FIG. 1. The direct link architecture is applicable where Internet infrastructure is not well established or fast response is desired for user navigation or other location specific information services. Illustratively, T1, Frame Relay, etc. linked by a LAN or WAN are appropriate for direct link **205**. In another embodiment, direct links **205** may be implemented as hard-wired connections between wireless carrier **203** and navigation server **207** where wireless carrier **203** and navigation server **207** are collocated in a central office.

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FIG. 3 is an illustrative flow chart showing the steps for communication between client and server in a real-time distributed navigation system according to one embodiment of the present invention. In step **301**, a user inputs a destination to a client wherein the client may be integrated with a mobile communication device (e.g. PDA, cellular telephone, etc.). The destination information may be input by voice, by interfacing with the mobile communication device, or by selecting a location from a stored list of addresses. A voice input may be available in multiple languages and the destination may be selected by various methods. In one embodiment, the user may designate to the client a new destination address by means of an interface attached to the mobile communication device. In an alternative embodiment, the user may select from a list of locations such as a list of the user's most recently used destinations, an address list of the user's frequently used destinations (e.g. office address, home address, etc.), a user recorded waypoint, or a preplanned trip list that may be stored in the user's preference

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settings. Moreover, a destination may be a detailed address such as a home address comprising a building number, a street name, a city name, a state, and a zip code; or a significant landmark such as a major highway.

5 In step **303**, a server obtains from the client a set of initial user position information sent along with a request for navigation instructions. In one embodiment, the client comprises a device such as wireless device **101** discussed with reference to FIG. 1. The server comprises a device such as navigation server **109** also discussed with reference to FIG. 1. In one exemplary embodiment, the client queries a positioning
10 system, such as a GPS system or other positioning systems, to acquire the initial position coordinates associated with the user. In step **305**, the server determines the user's initial position according to the initial user position information. For additional detail related to determination of user's initial position, refer to co-pending U.S. patent application Ser.
No. 10/408325, entitled "Method and System For Prediction-Based Distributed
15 Navigation", by Chao et al., filed on April 8, 2003, herein incorporated in its entirety by reference.

Moreover, a position contains various degrees of inaccuracies. For example, most GPS receivers can provide position information accurate to within a range of
20 approximately 50 meters, i.e., an inaccuracy of around 50 meters. There are a number of known factors that may affect the accuracy of a position determination. For instance, weather conditions may affect the accuracy of a GPS position determination. In one embodiment of the invention, a position, in addition to information defining the position

of an object, is also associated with an estimated error range. One skilled in the art appreciates that the error of a positioning system is estimated based upon the characteristics of the positioning device and other factors including weather and receiving conditions. Therefore, whether or not a position is ambiguous may be dependent upon
5 many factors including, but not limited to: the accuracy associated with the position; attributes of a road network; recent traveling history; and map accuracy. In one exemplary embodiment, the set of initial user location information indicates an ambiguous user position wherein the user may be situated in one or several possible positions, and the server must resolve the ambiguity before a determination can be made
10 of the user's initial position. For additional detail related to ambiguity determination, ambiguity reduction, and user location selection, refer to issued U.S. patent application Ser. No. 6,266,615 entitled "Method And System For An Interactive And Real-Time Distributed Navigation System" by HaiPing Jin, filed on July 24, 2001, herein incorporated in its entirety by reference.

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In another embodiment, the server determines that the user's position does not comprise an actual address. For example, the user may be located in the middle of a parking structure not having its own address. The server may then direct the user by providing directional arrows to a known street before calculating a route to the
20 destination.

Referring now back to step 305, in addition to determining a user's initial position, the server calculates a nominal route from the user's initial position to the

destination selected in step **301**. For additional detail related to nominal route calculation, refer to co-pending U.S. patent application Ser. No. 10/408325, entitled “Method and System For Prediction-Based Distributed Navigation”, by Chao et al., filed on April 8, 2003, herein incorporated in its entirety by reference. In step **307**, the client
5 receives navigation information related to the nominal route from the server.

The amount and/or type of navigation information received in step **307** may depend on factors such as user-designated settings or storage and/or processing capabilities of the client. In one embodiment of the present invention, the client receives
10 navigation information for the entire nominal route from the user’s initial position to the destination.

In a second embodiment of the present invention, the client receives navigation information for a partial nominal route. The amount of information received by the client
15 may be a user setting or limited by client storage and/or processing capabilities.

In a third embodiment of the present invention, in addition to information related to the nominal route, the client receives mapping information related to a corridor area surrounding the nominal route. FIG. 5 is an illustration of a nominal route and a
20 surrounding corridor area comprising: a user initial position denoted **IP**, a destination denoted **Dest**, a nominal route denoted **NR**, and a corridor area denoted **CA**. The corridor area **CA** comprises an area surrounding the nominal route. In one exemplary embodiment, the corridor area **CA** is defined by a constant radius on either side of the

nominal route **NR** wherein radius **R1L**, **R1R**, **R2L**, and **R2R** shown in FIG. 5 are equal regardless of where the radius measurements are made along the nominal route **NR**. In an alternate embodiment, the corridor area **CA** is defined by varying distances along the nominal route **NR**, wherein **R1L**, **R1R**, **R2L**, and **R2R** shown in FIG. 5 may be four
5 distinct values independent of each another.

Referring now back to step **307** of FIG. 3, the client may receive navigation information comprising nominal route navigation information as well as corridor mapping information in various combinations. In one exemplary embodiment, the client
10 receives navigation information comprising information for the entire nominal route and corridor mapping information along the entire nominal route.

In a second exemplary embodiment, the client receives navigation information comprising the entire nominal route but only partial corridor mapping information along
15 the nominal route. The amount of corridor mapping information received may depend on factors such as user settings or client storage and/or processing capabilities. Moreover, corridor mapping information may not include all streets within the established corridor area, optimizations may be made with techniques such as including only information related to those streets that can provide an alternate route to the destination or can provide
20 a path back to the nominal route once deviation from the nominal route occurs.

In one embodiment, the nominal route may be divided into several sections of constant (e.g. 100 feet per section) or varying (e.g. 50 feet from the user initial position

for the first section, 100 feet for the second section, etc.) distances, and the client receives and stores corridor mapping information for the next section at the end of the current section or the beginning of the next section. In an embodiment where the section lengths are not constant, the length of each section may rely on various factors such as the street density of the corridor area surrounding the section. Moreover, regardless of how the nominal route is divided, the client schedules the query of further sections of the route based on factors such as distance consumption and/or user speed. Once the user has traveled into the next section on the route, corridor mapping information for the previous section may be discarded from storage.

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In a third embodiment, the client receives navigation information for partial nominal route along with partial corridor mapping information.

Referring now back to step 309 of FIG. 3, having received the navigation information in step 307, the client presents turn-by-turn navigation guidance to the user. For further detail related to navigation message display, refer to issued U.S. patent application Ser. No. 6,266,615 entitled "Method And System For An Interactive And Real-Time Distributed Navigation System" by HaiPing Jin, issued on July 24, 2001, herein incorporated in its entirety by reference. In one embodiment, the client provides warnings for upcoming tight turns, the warnings may be triggered by factors such as user travel speed, angle of the turn, etc. In another embodiment, the client provides a dynamic local map via a graphic user interface to the user in order to give the user more comprehensive guidance. Moreover, the client continuously queries a positioning system

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such as GPS to track the user's position. Based on the user's current position coordinates, the client may determine that the user has reached the destination and announce the appropriate arrival message to the user in step 317.

5 In step 311, the user's position coordinates may indicate that a deviation from the nominal route has occurred or the user may alert the navigation system that the user has deviated from the calculated route to the destination, and the server and/or the client need to calculate a reroute to the destination in step 313. In one embodiment, a predefined or user and/or system set threshold value is used to determine whether or not the user has
10 deviated from the nominal route. The threshold by which deviation is determined may vary depending on the area in which the user is traveling. For example, the threshold may be set relatively low in environments that comprise little noise such as a sparsely populated area or a highway where the positioning measurements are relatively reliable; and the threshold may be set relatively high in environments that comprising a lot of
15 noise such as a business district of a downtown urban area where a multitude of high-rise structures may impair the accuracy of the positioning system. In another embodiment, the deviation detection may be a feature set by user preference and can be turned on or off as desired.

20 Furthermore, reroute calculation may be assigned either entirely to the server, entirely to the client, or divided between the server and the client. Reroute calculation is assigned according to the corridor mapping information stored in the client. In one embodiment, the server is assigned all reroute calculation wherein the corridor mapping

information stored in the client does not include a route from the user's current position to the destination, nor does the corridor mapping information include a path from the user's current position back to the nominal route. In a second embodiment, the client is assigned all reroute calculation wherein the corridor mapping information stored in the client does include at least one route from the user's current position to the destination, or at least one route from the user's current position back to the nominal route. In a third embodiment, the client does not have mapping information that would enable a full reroute independent of the server, however, the client calculates a route that leads the user toward the destination simultaneously as it communicates with the server for a full reroute.

In one embodiment, deviation has occurred, the client cannot independently reroute the user to the destination, and there does not exist a network available between the client and the server for communication. The client may then reroute the user back to the nominal route before presenting the client with navigation guidance for the nominal route again.

In another embodiment, the client and/or the server match the deviation to a pattern shown by previous deviations and reroutes according to the established deviation pattern. For example, rather than staying on the calculated route, the user has consistently selected a route parallel to the calculated route, and the client and/or server may then reroute via streets and/or highways parallel to the previous route rather than using the previous route.

Once a new route to the destination has been calculated in step **313**, the process loops back to step **307**.

5 FIG. 4 is an illustrative flow chart showing the steps for communication between client and server in a real-time distributed navigation system according to a second embodiment of the present invention. As shown in FIG. 4, steps **401-417** are substantially the same as their counterparts in FIG. 3, the client shown in FIG. 4 checks for the occurrence of event triggered communication between the client and the server in
10 addition to determining whether or not the destination has been reached and verifying if a route deviation has occurred.

 In step **416**, the client determines if a predetermined event set to trigger communication between the client and the server has occurred. A predetermined event
15 may be one of several events such as the need to obtain additional navigation information from the server where the client receives only partial navigation information in step **407**, or a periodic event for obtaining navigation and/or other updates (e.g. advertisements, weather, traffic, etc.) related to the calculated route from the server. Moreover, the predetermined event may be preset by the user and/or by the distributed navigation
20 system as default settings.

 If a communication is triggered, in step **418**, the client sends a request to the server for additional information (e.g. additional route information, additional corridor

information, etc.) and/or other updates (e.g. advertisements, weather, traffic, etc.). In step 420, the server responds by sending the requested information to the client. Once the client receives the requested information, it processes the information in step 422.

5 In one exemplary embodiment, the client processes the received information and determines whether the additional information significantly affects the calculated route to the destination. If the client determines that the received updates do not significantly impact the calculated route, the client processes the update information and loops back to step 409. However, if the client determines that the received updates significantly affect
10 the calculated route (e.g. severe weather conditions, traffic accidents, etc.), the client proceeds to display the relevant update to the user along with a reroute option. In step 426, the client verifies whether the user has selected to reroute in response to the displayed update information. If the user has not chosen to reroute, the client continues to display navigation instructions to the user according to the calculated route. However,
15 if the user does choose to reroute, a new route is calculated in step 413 and the client will then display navigation instructions of the recalculated route to the user.

 The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be
20 exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the arts to best

utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.

5 For example, in a further embodiment, where wireless device **101** is equipped with directional capabilities such as through the use of gyroscope, geomagnetic sensing, or GPS provided heading, the system provides real-time directional as well as navigational information. Illustratively, the system determines that the user must proceed north and the user is facing north, a device displays an upward pointing arrow indicating
10 that the user should proceed straight ahead. However, where the user must proceed north and he is facing south, the device display shows a downward pointing arrow indicating that the user should proceed backward or, more reasonably, turn around to face north and then proceed. In another implementation with a more enhanced display, more detailed and broader map information is displayed with more stylistic prompts to the user.

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 The invention further allows for the wireless device to be connected to an accessory display. For example, a wireless device **101** appropriate for walking is enhanced by interfacing with a device with additional features such as a car-mounted display or portable computer to become better equipped for automobile navigation. In
20 certain embodiments of the invention, the accessory device provides, without limitation, enhanced display capabilities, enhanced memory capacity, increased computational power, or increased throughput.

Moreover, although steps **311** and **315** illustrated in FIG. 3 are shown to be processed in parallel, the illustration is not meant to be limiting and the steps may be processed in series (the order of which may not be significant) or processed in parallel by multiple threads. Similarly, steps **411**, **415**, and **416** may be processed in series (the order of which may not be significant) or processed in parallel by multiple threads.